



**Testimony of T. J. Glauthier**  
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Congress of the United States  
House of Representatives  
Committee on Science  
Hearing on "Keeping the Lights On: Removing Barriers to Technology to Prevent Blackouts"  
September 25, 2003

Thank you, Madam Chair, I am T. J. Glauthier, President & CEO of the Electricity Innovation Institute, an affiliate of EPRI, the Electric Power Research Institute. With me today is Dejan Sobajic, Director of Grid Reliability and Power Markets at EPRI.

As you know, EPRI is a non-profit, tax-exempt, scientific organization formed by U.S. electric utilities in 1972 to manage a national, public-private collaborative research program on behalf of EPRI members, their customers, and society. Today EPRI has more than 1,000 members, including utilities of all owner types (both U.S.-based and international), independent system operators (ISOs), independent power producers, and government agencies, collectively funding an electricity-related scientific research and technology development program that spans every aspect of power generation, delivery, and use.

The Electricity Innovation Institute (E2I), formed two years ago by the EPRI Board of Directors as an affiliated non-profit, public benefit organization, sponsors longer-term, strategic R&D programs through public-private partnerships. Its Board of Directors is primarily composed of independent, bipartisan, public representatives.

E2I is already actively engaged in modernizing the electricity grid. For example, with technical support from EPRI, 18 months ago we began a public-private R&D partnership to design and develop the system of technologies enabling a self-healing, 'smart grid.' This partnership involves a number of public and private utility companies, the Department of Energy (DOE), several states, and the high tech industry. It has one multi-million dollar contract underway, with a team that includes General Electric, Lucent Technologies and others, to design an 'open architecture' for the smart grid.

EPRI and E2I actively support the dialogue on national energy legislation by providing objective information and knowledge on energy technology, the electricity system and related R&D issues.

I sincerely appreciate the opportunity to address this distinguished Committee on a subject about which we are all concerned. The electric power system represents *the* fundamental national infrastructure, upon which all other infrastructures depend for their daily operations. As we learned from the recent Northeast blackout, without electricity, municipal water pumps don't work, vehicular traffic grinds to a halt at intersections, subway trains stop between stations, and elevators stop between floors. The August 14<sup>th</sup>

blackout also illustrated how vulnerable a regional power network can be to cascading outages caused by initially small—and still not fully understood—local problems.

In response to the Committee's request, my testimony today provides some of EPRI's and E2I's views on technology issues that require further attention to improve the effectiveness and reliability of the nation's interconnected power systems. This testimony will be supplemented with a matrix table as requested by the Committee.

### **Context for power reliability**

Power system reliability is the product of many activities—planning, maintenance, operations, regulatory and reliability standards—all of which must be considered as the nation makes the transition over the longer term to a more efficient and effective power delivery system. While there are specific technologies that can be more widely applied to improve reliability both in the near- and intermediate-term, the inescapable reality is that there must be more than simply sufficient capacity in both generation and transmission in order for the system to operate reliably.

The emergence of a competitive market in wholesale power transactions over the past decade has consumed much of the operating margin in transmission capacity that traditionally existed and helped to avert outages. Moreover, a lack of incentives for continuing investment in both new generating capacity and power delivery infrastructure has left the overall system much more vulnerable to the weakening effects of what would normally be low-level, isolated events and disturbances.

Two years ago, in response to the events of September 11, 2001, an inter-disciplinary EPRI team prepared the *Electricity Infrastructure Security Assessment*, a preliminary analysis of potential terrorist threats to the U.S. electricity system. Out of this effort grew the Infrastructure Security Initiative (ISI), which has undertaken a short-term, tightly focused effort to identify key vulnerabilities and design immediately applicable countermeasures. The initial phase of the ISI has been completed and work is now underway to implement some of the technological solutions identified. More recently, E2I and EPRI began work with the Department of Homeland Security (DHS) to establish the National Electric Infrastructure Security Monitoring System (NESEC). This system will enable DHS to monitor the security of the national power grid in real time and can be used to identify and diagnose unusual events that might signal a terrorist attack in its early stages. Such a system could also be used to monitor grid operations for disturbances with potential to impact reliability.

The electric power industry is one of the most data intensive and computing power-reliant of all industries, with Supervisory Control and Data Acquisition (SCADA) systems collecting data and sending control signals over wide geographical regions, in conjunction with the analytical functions performed by highly computerized Energy Management Systems (EMS).

EPRI is actively supporting the U.S.-Canada Joint Task Force on the power outage of August 14<sup>th</sup>, working with DOE and the North American Electric Reliability Council (NERC). Based on information assembled and published by the task force so far, some basic, bottom-line preliminary implications can be drawn. One is that better, more

complete information about system conditions in the affected region could have enabled quicker response by the various system operators, which might have helped avert so widespread an outage.

A significant weakness of the North American power system is that, despite the computing power that is applied, not all parts of the power system are presently covered by SCADA and EMS systems. There are gaps in coverage, and some critical parameters must be computed from other measurements. EPRI strongly recommends that the industry move toward completing the data picture by ensuring that all transmission facilities down to the 169-kilovolt level are fully measurable and observable—in real time—for five key parameters: active power, reactive power, current, voltage, and frequency. In addition, each of the 150 individual control areas need to implement complete SCADA coverage for the entire system.

### **Seeing the bigger picture**

System operators also need the capability for a wide-area view of what is happening in neighboring control areas. This would represent a major improvement over existing conditions, under which operators cannot access the same level of information on neighboring systems that they have on their own system. Two years ago, in cooperation with NERC, EPRI conducted an R&D project sponsored under the industry-funded Reliability Initiative, which demonstrated an integrated, real-time visualization of the nationwide interconnected system, incorporating data on critical operating measurements from each control center, using the Internet for communication. There are similar demonstration efforts underway by other organizations as well. For a relatively modest cost, such a system could be made available to all system operators.

A related issue involves interpretation and analysis of the operating data from SCADA and EMS systems. EMS application software programs known as state estimators are employed to process data and compute values for system parameters that are not measured. Results are critical for doing more complex analyses, such as contingency analyses of the impact of losing various system elements, such as power plants or transmission lines. Yet because of low confidence in the computed results for real-time decision-making, very few control center EMS state estimators are fully utilized today. EPRI believes that credible, complete information from operational state estimators is essential for reliability and should be required in all control areas.

### **Near-term solutions**

One relatively simple technology developed by EPRI and successfully demonstrated by several utilities could contribute to improved system reliability by enabling increased confidence of safe loading levels for transmission lines above their conservative static ratings. By integrating real-time sensor data on ambient temperature, wind speed, and line sag on specific circuits, EPRI's Dynamic Thermal Circuit Rating (DTCR) system allows operators to move more power on lines with reduced risk of thermal overload. DTCR is low-cost and can be quickly deployed on thermally constrained lines. Such dynamic line ratings, along with more complete SCADA coverage, would represent key inputs for more probabilistic-based contingency analyses of system instability. Such probabilistic-based analyses could extend the scope of contingencies considered from the loss of a single transmission line or generating source (N-1 contingency), which is the

current criterion, to the simultaneous loss of multiple lines or generators (N-2 contingency).

On the hardware side of T&D systems, a mid-term solution for increasing the capacity of existing transmission corridors may soon be ready for commercial deployment: advanced high-temperature, low-sag conductors. These advanced conductors have the potential to increase current carrying capacity of thermally constrained transmission lines by as much as 30% or more. Five new types of aluminum conductor designs, reinforced or supported with steel or composite material, are being investigated by EPRI in collaboration with member utilities. One type is already under field test in a project with CenterPoint Energy in Houston; it also promises more rapid installation, since it has already been demonstrated that the conductors can be strung while energized. This work complements related ongoing activity supported by DOE's Office of Electric Transmission and Distribution, including testing activity at Oak Ridge National Laboratory.

### **Facing up to loop flows**

Numerous knowledgeable power system engineers have warned for many years that the phenomenon of loop flow would eventually have important implications for reliability, but those warnings have largely gone unheeded with the emergence of a competitive, wholesale bulk electricity market. Preliminary indications are that loop flows of power around the Lake Erie region may have played a role in the Aug. 14<sup>th</sup> blackout.

Loop flows are a key unresolved issue facing the industry today in terms how the power system status appears to operators, yet such flows generally are not accounted for in day-to-day operations. Loop flows result from the basic physics of electricity, which follows all available paths of least resistance, rather than a single line on a contract path from point A to point B. These loop flows have been present ever since power grids began to become interconnected, but only recently have loop flows reached a level sufficient to cause problems. With today's reduced operating margins of transmission capacity, they can make the difference between safe operating conditions and system overload.

Loop flows can be controlled with solid-state power electronics technology, such as Flexible AC Transmission Systems (FACTS) technology developed by EPRI and power equipment vendors, but specific operating practices are necessary that require EMS state estimator information to establish proper settings for mitigation. FACTS technologies deployed in various configurations promise a new dimension of high-speed control flexibility to change the power system state and react to changes in ways that we cannot today. However, FACTS technologies are still emerging and their cost and size must be further reduced through continued R&D efforts before they are economical for widespread deployment.

In addition to DTCR and improved data exchange standards and system information coverage, other near-term steps that could contribute to improved reliability include improved operator training, both for normal operation under heavy loading conditions and for service restoration from outages. Operators require more information in order to perform restoration procedures than are required under normal operating conditions. Reiterating the importance of a holistic approach to reliability, transmission and distribution infrastructure maintenance should be afforded the same priority as system

planning, operations, and energy marketing that are addressed by standing NERC standards committees.

Given that energy legislation now under consideration by the Congress would establish mandatory, enforceable reliability standards under NERC supervision, such standards should specifically address requirements for the provision of, and compensation for, reactive power for voltage support. Although the significance of this somewhat arcane component of alternating current transmission is lost on many people not trained in electrical engineering, its critical importance in the operation of interconnected systems and long distance transmission cannot be overemphasized. Reactive power is a non-billable, but essential, component of real or active power that helps maintain voltage and is critical for magnetizing the coils in large inductive loads so they can start up and begin drawing real power.

### **Intermediate term measures**

Beyond the more immediate steps and technologies available for boosting power system reliability, development of a number of emerging technologies that are still not yet ready for commercial deployment could benefit from increased industry and government support for demonstration efforts. These include the demonstration and integration of new intersystem communication standards based on open protocols to enable data exchange among equipment from different vendors, including SCADA and EMS systems. Two prime examples of such standards are the EPRI-developed Utility Communications Architecture for connecting equipment from different vendors and the Inter-Control Area Communication Protocol for linking control centers and regional transmission organizations.

As described more fully below, EPRI's ultimate vision for the future of power delivery is an electronic, self-healing, adaptive 'smart' power grid. However, realizing this vision fully will require development, demonstration, and integration over the next decade of key elements that do not yet exist, such as intelligent software to reconfigure systems to prevent blackouts. Yet features of the self-healing grid of the future can be demonstrated today using off-the-shelf, recently developed technologies. Such demonstrations could begin providing near-term benefits during the next several years, before the complete vision of a 'smart' grid becomes reality within the next decade.

The Electricity Innovation Institute (E2I), a non-profit affiliate of EPRI established to pursue public-private partnerships for strategic electricity R&D, is proposing just such a partnership to demonstrate Dynamic Risk and Reliability Management (DRRM). The proposed effort would develop and demonstrate a set of real-time tools to enable system operators to see and quickly react to grid conditions that threaten to cause outages. Unlike existing technologies, the tool set will combine a picture of real-time vulnerabilities with an assessment of the status of grid components to pinpoint "hot spots," or areas where equipment failure could precipitate a widespread outage. Existing tools focus on monitoring the health of equipment *or* monitoring the status of the grid, but have not yet been effectively combined into one tool capable of providing a clear picture of overall risk. DRRM requires all the previously mentioned short-term improvements in data integrity and coverage in order to be effective.

E2I is proposing to take maximum advantage of ongoing R&D to develop and implement a working demonstration of DRRM in the shortest possible time. Tools such as the EPRI-developed Maintenance Management Workstation for transmission substations, Probabilistic Risk Assessment for contingency analyses, Visualization of transmission conditions via EPRI's Community Activity Room™ software, Transformer Advisor expert diagnostic system, and others will be brought together to support DRRM development.

E2I is already engaged with several utility partners anxious to demonstrate DRRM tools on their transmission systems. The proposed work will require investment of \$10 million to \$20 million and take approximately two years to complete. Once demonstrated, DRRM will be designed for rapid deployment by transmission operators and RTOs. Results of using DRRM would provide the quantitative basis to support risk-based revisions to contingency analyses, reliability criteria, and operating practices.

### **Adaptive, self-healing response at the speed of light**

The smart grid encompasses both the long distance transmission system and the local distribution systems. Central to the concept is that it incorporate ubiquitous sensors throughout the entire delivery system and facilities, employ instant communications and computing power, and use solid-state power electronics to sense and, where needed, control power flows and mitigate disturbances instantly. The upgraded system will have the ability to read and diagnose problems, and in the event of a disruption from either natural or man-made causes, it will be 'self-healing' by automatically isolating affected areas and re-routing power to keep the rest of the system up and running. It will be alert to problems as they unfold, and able to respond at the speed of light.

Another advantage of the smart grid is that it will be able to support a more diverse and complex network of energy technologies. Specifically, it will be able to seamlessly integrate an array of locally installed, distributed power sources, such as fuel cells, solar power, and combined heat and power systems, with traditional central-station power generation. This will give the system greater resilience, enhance security and improve reliability. It will also provide a network to support new, more energy efficient appliances and machinery, and offer intelligent energy management systems in homes and businesses. For utilities and their customers, 'smart' grid technology could also enable the incorporation of significant amounts of electricity stored in battery systems, flywheels, compressed-air, and other forms of storage, when they are economical, for load management, voltage support, frequency regulation, and other beneficial applications, including providing a buffer between sensitive equipment and momentary power disturbances.

The enhanced security, quality, reliability, availability, and efficiency of electric power from such a smart grid will yield significant benefits. It will strengthen the essential infrastructure that sustains our homeland security. Moreover, it will reduce the cost of power disturbances to the economy, which have been estimated by EPRI to be at least \$100 billion per year – and that's in a normal year, not including extreme events, such as the recent outage. Further, by being better able to support the digital technology of business and industry, the smart grid will also enable a new phase of entrepreneurial

innovation, which will in turn accelerate energy efficiency, productivity and economic growth for the nation.

The economic benefits of the smart grid are difficult to predict in advance, but they will consist of two parts. These are stemming the losses to the U.S. economy from power disturbances of all kinds, which are now on the order of 1% of U.S. gross domestic product, and taking the brake off of economic growth that can be imposed by an aging infrastructure.

### ***Electricity Sector Framework for the Future***

On August 25, 2003, EPRI released a report on the current challenges facing the electricity sector in the U.S., outlining a Framework for Action. The report, the *Electricity Sector Framework for the Future* (ESFF), was completed prior to the August 14 outage, and was developed over the past year under the leadership and direction of the EPRI Board of Directors.

EPRI engaged more than 100 organizations and held a series of regional workshops, including a diverse group of stakeholders—customers, suppliers, elected officials, environmentalists, and others—in producing the Framework. That dialogue provided valuable insights into the causes of problems, such as the disincentives for investment and modernization in transmission facilities, which have become much more widely recognized since the August outage.

The ESFF report lays out a coherent vision of future risks and opportunities, and of a number of the issues that must be dealt with in order to reach that future. It also reflects viewpoints widely shared by the broader electricity stakeholder community that contributed to its development. Its vision of the future will be based on a transformed electricity infrastructure that is secure, reliable, environmentally friendly, and imbued with the flexibility and resilience that will come from modern digital electronics, communications, and advanced computing.

But to arrive at that future, many parties must take action in the near term. The report calls upon Congress to take action in a number of areas, such as establishing mandatory reliability standards, clarifying regulatory jurisdictions, and helping to restore investor confidence in the electricity sector so that needed investments can be made.

EPRI President and CEO Kurt Yeager and I presented a staff briefing on the *Electricity Sector Framework for the Future* that was hosted by this committee on September 11, 2003. The full ESFF report is also publicly available.

### **Recommended Congressional action**

Current legislation under consideration by Congress contains some good provisions in support of technology development, but the national transformation of the grid is so important that it requires stronger action and support from the Congress in the energy bill. EPRI submitted specific legislative language, focusing on the technology and R&D areas that we believe are vital to modernizing the nation's electricity transmission and distribution grid, to the House and Senate leadership who are currently meeting to discuss

HR 6. In addition, there are four key areas of technology policy that the energy legislation should address, as described below:

***1. Establish the ‘Smart Grid’ as a national priority***

Congress can provide real leadership for the country by establishing the ‘smart grid’ as national policy and as a national priority in the legislation. By articulating this as national policy and offering a compelling vision for the country, Congress can increase the pace and level of commitment to the modernization of the electricity grid.

That action itself will help to focus the attention of the federal and state agencies and the utility industry and others in the private sector. By making the smart grid a national priority, Congress will be sending a clear message that this modernization is critically important in all sectors and in all regions of the country, and that deployment should be undertaken rapidly.

***2. Authorize increased funding for R&D and demonstrations***

To carry through with the priority of the smart grid, the legislation should include significantly increased development funding. In particular, it should contain authorization for significant additional appropriations over the next five years for programs managed by DOE, working in partnership with the private sector.

The Administration has taken some steps in this direction in its earlier budgets, but this demands even stronger, more targeted action by the Congress. Support is needed in two areas. One is more extensive R&D in the relevant technologies, needed to provide all the components of the smart grid. The other area is to support an aggressive program of technology demonstration and early deployment projects with the states and the industry, to prove out these components, and to refine the systems engineering which integrates all these technologies in real-world settings.

EPRI estimates that this research and demonstration program will require increased federal funding for R&D on the scale of approximately \$1 billion, spread out over five years, with the private sector contributing a significant amount of matching funding. These R&D and demonstration funds represent an investment that will stimulate deployment expenditures in the range of \$100 billion from the owners and operators of the smart grid, spread out over a decade.

***3. Recognize a public/private institutional role for R&D***

It is vitally important that the legislation recognize that this R&D and demonstration program should be carried out in partnership with the private sector. The government can sponsor excellent technical research. However, it is the industry that will ultimately be responsible for building, maintaining and operating the electricity system to keep the lights on and the computers humming. And as we’ve just seen, there is little tolerance for error—it has to work all the time—so this is more than a research program, it is an engineering and operations program on which the country will rely.

***4. Develop an approach for long-term funding of deployment***

A national approach is needed to fund the full-scale deployment of the smart grid throughout the country. The scale of deploying the technology, and doing the detailed

systems engineering to make it work as a seamless network, will require significant levels of investment, estimated at \$100 billion over a decade.

These implementation costs for the smart grid will be an investment in the infrastructure of the economy. This investment will pay back quickly in terms of reduced costs of power disturbances and increased rates of economic growth.

Nevertheless, this is a substantial challenge for an industry that is already under financial strain, and is lacking investment incentives for the grid. It's a challenge, too, because this investment must be new and additional to what the industry and its customers are already providing to keep the current systems operating. A business-as-usual approach will not be sufficient.

We need a national financing approach or mechanism that will be effective, fair, and equitable to all parts of society. This will require agreement among the industry, state regulatory commissions, customers and other stakeholders as to how that should be carried out.

The answer to this will undoubtedly take extended discussions with the various stakeholder groups. Rather than rush to judgment on one or another specific approach, we urge that Congress include language in the energy bill to direct the Administration to develop an appropriate recommendation. The Administration should work with the industry, the states, customers, and other to develop its recommendation and report back to Congress at a specific time, no later than one year after enactment.

### **Conclusion**

As noted earlier, the cost of developing and deploying the smart grid for the country should be thought of as an investment in the future—in a secure, reliable, and entrepreneurial future—that will pay back handsomely over many decades to come as the energy backbone of the 21st century.

Thank you, Madam Chair. I welcome any questions you may have.